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PROGRESS REPORT ON IRRIGATION EXPERIMENTS IN WILLAMETTE VALLEY, OREGON.

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INTRODUCTION.

The investigations dealt with in this report have for their object a determination of the value of irrigation for increasing and insuring the productiveness of the agricultural lands of the Willamette Valley, Oregon.

This valley contains perhaps the largest single body of tillable land, outside of the great Sacramento and San Joaquin valleys in California, in the Pacific Coast or Rocky Mountain States. It is also one of the oldest-settled sections of the West, a large part of its prairie and bottom land having been in cultivation for more than fifty years. The rainfall during the winter months is very heavy, but during the summer months it is so light as to constitute almost an arid condition in so far as the production of agricultural crops is concerned.

In the early days and up to within the last few years grain growing has been the predominant industry. The moist, early springs and dry summers were admirably adapted to the production of cereals, and it was but natural that the raising of grain should have been the leading industry. However, under the strain of constant cropping to wheat and with only poor, shallow cultivation and no fertilization the soil gradually failed to yield profitable crops of grain. As a natural result of these conditions a change in agricultural methods has been taking place within the last few years, and the wheat ranch with its 320 to 640 acres or more of poorly cultivated soil is giving place to the small diversified farm with its crop rotation and its intensive cultivation.

But the climate is not well adapted to this new system of agriculture. Grain was ripe and ready for harvest before the dry summer months came on, while the crops now being raised—clover, vetch, hops, small fruits, and vegetables—extend their growth well into or through the dry season, if given the opportunity, and often suffer from a lack of sufficient moisture just at the time when needed to give the crop its best growth.

The purposes of the investigations now being made in the Willamette Valley by the irrigation investigations of this Office are to determine in a careful way just what benefits may be secured from the application of water to crops during the dry season, what expense may be incurred for irrigation, and what methods should be employed to produce the best results. Some progress has already been made toward the solution of these problems by a few who have been practicing irrigation in a small way, but little is known of their success outside of the immediate localities where the experiments were made, and even there little effort has been made to extend the practice.

A series of cooperative experiments was begun in the spring of 1907, the plans outlined including the following lines of work:

(1) The collection of information bearing on the value of irrigation, dealing with the subjects of water supply, rainfall, soil conditions, and the like.

(2) The determination of the value of irrigation to different crops, the best methods of preparing land and irrigating it, the proper time of application, and the various other practical questions connected with irrigation.

(3) The giving of advice and the lending of assistance to those who wish to begin irrigating.

To yield any conclusive results the experimental work must, of course, be extended over a period of years. For this reason no definite results can be reported at this time. However, it is deemed advisable that a report of progress be made and that such information as has been gathered and such suggestions as seem pertinent be published for the benefit of those who will undertake to irrigate lands in this valley.

PHYSICAL CHARACTERISTICS OF THE WILLAMETTE VALLEY.

LOCATION AND SIZE.

The Willamette Valley lies in the western part of Oregon between the high Cascade Mountains on the east and the Coast Range on the west. Its southern limit is the summit of the Calapooias, a spur of the Cascades, and its northern limit the Columbia River. The length

of the valley north and south is approximately 150 miles, and its width from summit to summit varies from 50 to 75 miles. Including its mountainous areas, the approximate area within the Willamette watershed is 8,000,000 acres. Of this considerably over one-half is timbered, mountainous area, the valley and foothill land proper approximating 3,000,000 acres.

STREAMS AND STREAM FLOW.

The dominant physical feature of the valley is its stream system. The Willamette River rises in the southeastern corner of the watershed in the junction of the Calapooias with the high Cascades. Flowing northerly, it follows the trough of the valley and empties into the Columbia at the northern extremity of the valley. From the Cascade Range on the east a network of tributaries make their way toward the trunk stream. Among these are several of the larger streams of the State, such as the Middle Fork, the McKenzie, the Santiam, the Molalla, and the Clackamas. There are a number of tributaries from the Coast Range on the west, but the flow of these is neither so large nor so constant as that which comes from the high watershed of the Cascades. Among the principal streams entering the valley from the west are the Coast Fork, the Tualatin, the Yamhill, the Luckiamute, and Marys rivers. The discharge of some of these streams during 1906 is given in the following table:

Discharge of Willamette River and its principal tributaries, 1906.[a]

Name of stream and place of measurement.	Discharge.				Run-off.	
	Maximum.	Minimum.	Mean.	Total.	Per square mile.	Depth.
	Cubic feet per second.	*Cubic feet per second.*	*Cubic feet per second.*	*Acre-feet.*	*Cubic feet per second.*	*Inches.*
Willamette River at Albany	52,800	2,810	12,600	9,060,000	2.59	34.93
Middle Fork at Jasper	16,400	800	4,020	2,900,000	2.77	37.49
Coast Fork, near Goshen	15,000	68	1,580	1,130,000	2.28	30.80
McKenzie, near Springfield	17,400	1,630	4,650	3,350,000	4.84	65.49
North Fork of Santiam at Mehama	36,200	700	3,930	2,830,000	5.31	71.67
South Fork of Santiam at Waterloo	36,900	192	3,510	2,520,000	5.48	73.78
Molalla, near Molalla	7,120	60	913	656,000	4.15	55.93
Clackamas, near Barton	25,100	818	3,730	2,690,000	4.66	62.91
Luckiamute, near Suver	9,450	37	1,090	784,000		

[a] U. S. Geol. Survey Water-Supply and Irrigation Paper No. 214.

Owing to the nature of the precipitation the streams have their heaviest discharge during the winter and spring months. As the summer flow of the streams has an important bearing upon the feasibility of irrigation the relation of the summer flow to the yearly flow is shown.

Yearly discharge and summer discharge of streams in Willamette Valley.

Name of stream.	Yearly discharge.	Discharge during July, August, and September.	
	Acre-feet.	*Acre-feet.*	*Per cent.*
Willamette	9,060,000	747,000	8
Middle Fork	2,900,000	215,600	7
Coast Fork	1,130,000	34,550	3
McKenzie	3,350,000	437,000	13
North Fork of Santiam	2,830,000	191,600	7
South Fork of Santiam	2,520,000	86,300	3
Molalla	656,000	26,230	4
Clackamas	2,690,000	192,300	7
Luckiamute	784,000	22,600	3

TOPOGRAPHY.

The mountainous portion of the Willamette drainage area comprises 5,000,000 acres or more. In the Cascades there are a number of high mountain peaks, among the most noted of which are Mount Hood, Mount Jefferson, and the Three Sisters. The elevation of the summit of the Cascades varies from 7,000 to 9,000 feet. The mountain slopes are very heavily timbered, affording excellent protection to the water supply coming from that side of the valley. The mountainous area merges into the valley area proper through a zone of low, rolling hill country that is more or less wooded. The floor of the valley is a series of smooth, level areas known as "prairies" or "plains," whose slope is extremely uniform and ranges from 4 to 15 feet per mile. The north end of the valley is more or less broken and cut into lesser valleys by a series of low, rolling hills and by the foothills spreading over a wider area. In the south end of the valley—from Eugene as far north as Salem—the floor of the valley, although much cut up by the various streams, is extremely even in slope and large bodies of level prairie land are to be found. Along the streams are bottom lands, usually more or less wooded.

SOILS.

The soils of the valley are largely of basaltic origin. They are quite variable in character, but in general they may be classified as follows:

Foothill soils.—These are confined to the higher rolling foothill section. As a rule they have better natural drainage and are more friable than the soils of the prairies. In sections of the valley the hill lands are a sandy loam merging into a gravelly loam, not always of great depth, but usually deep enough for successful cultivation. In the foothill section there is also a considerable area of what is locally called "shot" land, because many of the soil particles have the form of small pellets resembling shot.

Valley or prairie soils.—The soils of the floor of the valley are alluvial in character and of fine texture and clayey nature. The greater part of these soils, especially in the south end of the valley, may be classed as clay loams. The subsoil as a rule is of clay and in many sections beneath this clay subsoil is a stratum of fine gravel. In other sections this gravelly subsoil does not seem to exist, and in these sections, especially where the surface drainage is poor, the heavy winter rainfall saturates the soil and hinders cultivation early in the spring. It is in such sections as these that the so-called "white lands," that are so unproductive, appear. They occur in isolated seams and patches throughout the darker-colored loams, and are always found in low places and depressions where the drainage is poor and where during the entire winter season and far into the spring the land is under water. Except perhaps in the amount of humus contained, they have nearly the same chemical nature as the other clay loams that surround them, but they are compact and run together, i. e., more or less puddled.[a]

The soils of the valley that are likely to be most productive under irrigation are the friable clay loams of the prairies that have good underdrainage. These lands no longer yield good crops of wheat and now lie comparatively idle. The greater part of this land lies in the south end of the valley in Lane, Linn, Benton, and Marion counties.

Bottom soils.—Soils of this type are found along the river and creek bottoms that are more or less subject to overflow, and are therefore quite limited in extent. They are the richest soils in the valley, being composed of alluvial deposits of basaltic origin mixed with sand and a high percentage of vegetable matter. They are easily cultivated and are considered the most productive soils of the valley. What are commonly called "beaver-dam lands" belong to this type. Except where these soils have an extremely impervious subsoil or do not receive natural subirrigation from the higher lands, it is improbable that irrigation will ever be resorted to unless it be for some special use, such as market gardening. Of the three types of soils it may be expected that the prairie soils, by reason of their greater extent and because of their location and inability to withstand drought, will yield the largest return under irrigation.

[a] Experiments are now being conducted by this Office on a tract of land near Albany to determine the effect of underdrainage upon this type of soil, in the way of disposing of the surplus water it receives during the winter and spring, and putting the soil in condition for cultivation. The experiments were only begun the past season and as yet it is too early to forecast the result. It has been reported that a number of individuals have applied drainage to white lands with much success.

CLIMATE.

Although in the same latitude as Montreal, the Willamette Valley, because of its proximity to that part of the Pacific coast which is washed by the warm Japan current, has an extremely mild climate. There are no extremes of either heat or cold. Summer temperatures rarely exceed 100° and then only for a very few days during the season. From 85° to 90° is the usual maximum temperature for summer. The nights are always cool. In the winter the thermometer sometimes goes as low as 10° F., but never for any considerable period. Periods of mild temperature are frequent, and throughout most winters grass remains green in the meadows and pastures. The crop season proper extends from April 1 to about October 15, a period of nearly seven months. Cultivation can be begun as early as February 15 some seasons, but more often begins in March. Annuals, such as grain, planted at this time usually mature successfully before the summer dry period, unless a drought occurs in May or in the early part of June. Other crops whose growth extends into the dry summer months, unless favorably located on land that is naturally retentive of moisture, are apt to suffer in the dry months of July, August, and September.

The annual precipitation for the valley, excluding the mountainous and high foothill areas, is approximately 44 inches, very little of which comes in the form of snow. A summary of the precipitation records kept by the Weather Bureau at nine different points in the valley is given in the accompanying table. All of the stations mentioned are located in the bottom of the valley, the records showing the precipitation in those sections which are devoted to agriculture. Records have been kept at some of these stations for over forty years, but for the purpose of illustrating the character of rainfall—a matter which will be discussed quite freely later—the records for the last eleven years are deemed sufficient.

Annual precipitation at different points in Willamette Valley, 1897–1907.

Station.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
	Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
Eugene	38.55	-------	-------	-------	40.01	51.50	34.21	-------	-------	37.55	46.27
Albany	50.19	36.22	47.60	38.88	34.28	52.94	32.65	49.41	30.19	40.72	44.44
Corvallis	43.61	35.00	49.69	38.49	29.19	54.02	34.13	56.21	34.39	45.71	50.28
Monroe	-------	36.36	55.62	44.24	49.05	66.37	43.59	63.15	-------	48.08	56.92
Salem	46.53	34.19	48.12	37.22	37.42	-------	24.56	42.08	28.49	34.01	37.10
Mount Angel	49.85	42.23	-------	46.76	43.14	-------	35.37	49.56	37.86	50.80	59.39
McMinnville	55.07	38.93	56.58	47.52	51.75	61.97	40.32	53.35	35.30	-------	47.60
Portland	43.01	33.90	42.21	38.22	41.05	50.15	35.62	46.37	34.10	43.29	42.89
Forest Grove	-------	-------	-------	-------	-------	-------	43.13	65.88	36.69	51.63	-------
Average	46.70	36.70	49.90	41.60	40.70	56.10	35.90	53.20	33.90	43.90	48.11

Although the records might indicate that the south end of the valley receives slightly less moisture than the north end, the amount of variation is so small as to cause practically no difference in agricultural conditions. With different years the rainfall varies quite widely—from 25 inches at Salem in 1903 to 66 inches at Monroe in 1902. The greatest variation, however, occurs with the different seasons of the year. Over two-thirds of the yearly rainfall occurs during the winter season, November to March, while during the summer period, from June to September, very little precipitation occurs—less than 5 per cent of the yearly amount.

In the table which follows the rainfall for the three-month period from June 15 to September 15 is shown for the nine stations given in the preceding table.

Precipitation at different points in Willamette Valley from June 15 to September 15, 1897–1907.

Station.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
	Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
Eugene	3.58	------	4.18	2.46	1.31	2.85	3.83	------	1.04	2.47	1.76
Albany	5.66	2.19	4.77	3.44	.62	2.44	3.21	1.18	.76	1.83	1.95
Corvallis	3.65	.35	4.23	3.95	.48	1.62	1.89	1.17	.89	2.02	1.67
Monroe	------	1.83	4.15	------	------	1.63	3.08	.97	------	1.62	1.98
Salem	4.60	1.88	3.81	3.53	1.08	------	2.17	.98	1.42	1.84	2.41
Mount Angel	5.73	1.52	------	3.83	.95	2.30	3.45	1.44	2.48	1.99	4.35
McMinnville	4.13	2.47	6.04	------	1.48	1.91	2.63	.64	1.49	------	2.38
Portland	4.54	1.96	4.19	4.77	1.29	2.48	3.37	.96	2.83	2.25	2.62
Forest Grove	------	------	------	------	------	------	2.19	.53	1.70	1.32	------
Average	4.50	1.70	4.48	3.60	1.03	2.18	2.87	.98	1.58	1.91	2.31

THE NEED OF IRRIGATION.

The need of irrigation is not determined by the total amount of rainfall but by its distribution throughout the year. The distribution of the yearly rainfall of the Willamette Valley is shown in the accompanying diagram (fig. 1). This diagram is based upon all the available records that have been kept by the U. S. Weather Bureau at the nine stations given in the above table. The records at some of these stations have been kept for over forty years. The shortest period of observation, that at Monroe, is seven years. The average upon which the diagram is based may therefore be taken as well established.

From October to March approximately 75 per cent of the rainfall of the year occurs, leaving but 25 per cent or about 10 inches of rain for the six months of the dry season, from April to September, when many crops are making their greatest demand for moisture. During April, May, and the early part of June the rainfall in average years is abundant for all crops, and in some years more than abundant; but from about June 15 of each year to September 15 the rainfall averages but 2.5 inches, less than 1 inch per month, which is entirely

insufficient to maintain proper moisture conditions in the average soils of the valley.

To show that this condition is not confined to isolated years, and to bring out the relation of this three-month rainfall to the total annual rainfall, attention is directed to the accompanying diagram (fig. 2). This diagram is based upon an average of the observations during

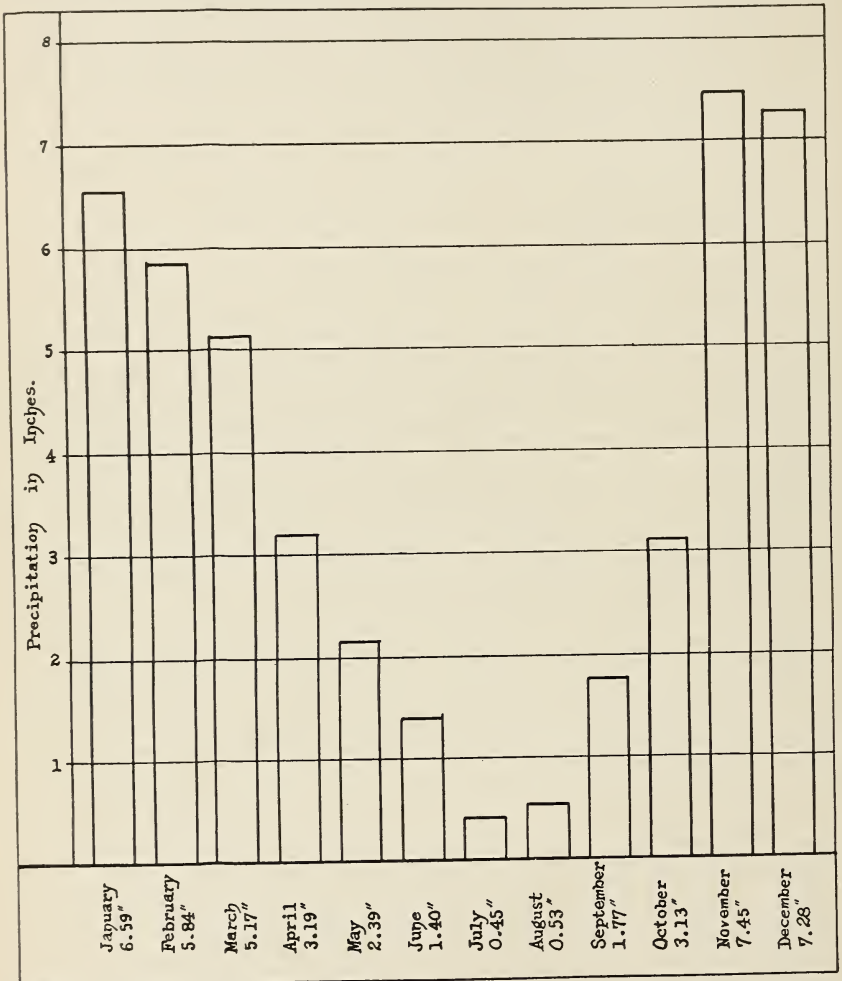

FIG. 1.—Diagram showing average monthly precipitation in Willamette Valley, Oregon.

the last eleven years at the nine stations given in the table. The shaded portions show the amount of rainfall occurring from June 15 to September 15 of each year. The clear area shows the total annual rainfall. The lower dotted line indicates the average precipitation during the summer period. The upper dotted line indicates the average yearly precipitation.

The character of the rainfall during the summer period must also be taken into account in considering the matter. The records show that the majority of the rains occurring in this period are little more

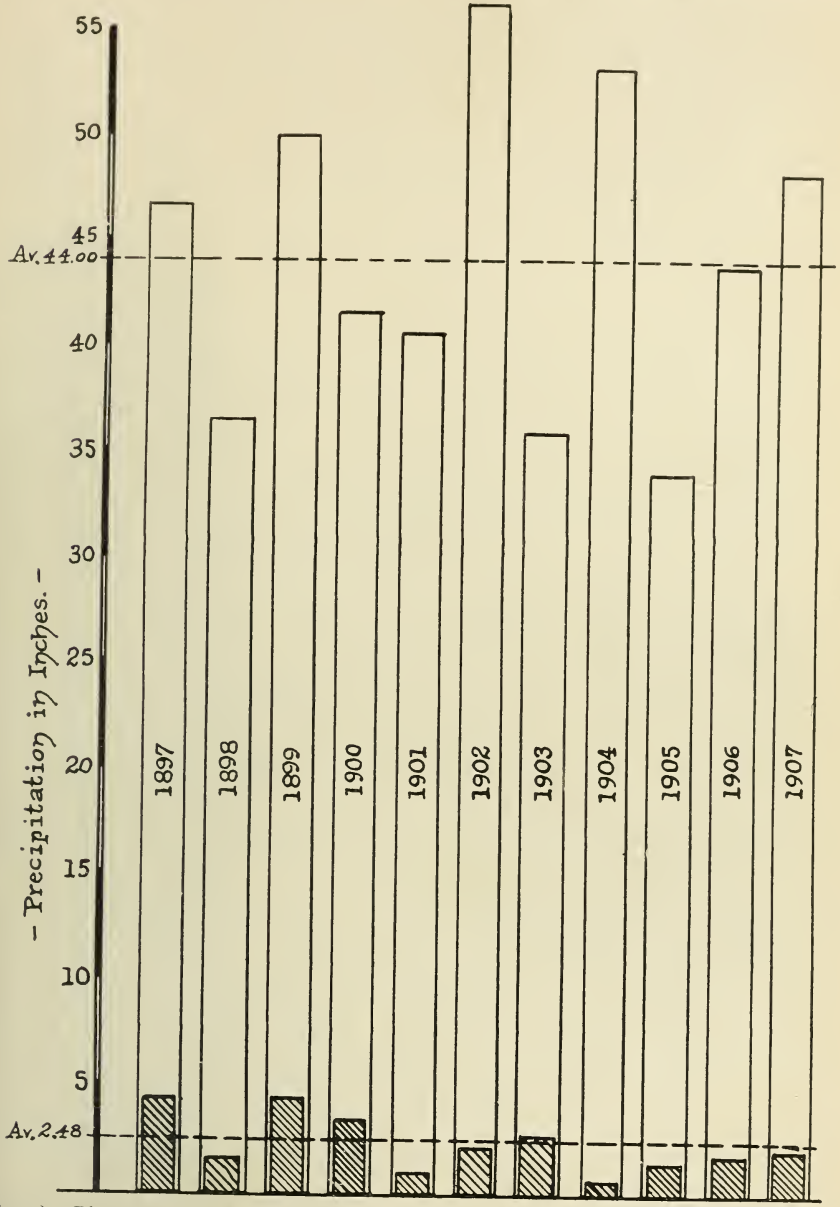

FIG. 2.—Diagram showing total annual precipitation and that occurring during summer months June 15 to September 15.

than showers, and although their aggregate makes a considerable showing, they are of little value to growing crops.

The season of 1907 illustrates this point very clearly. The total amount of rainfall and its distribution were about normal. The summer rainfall came in three distinct shower periods—the first occurring in the latter part of June and the first part of July, the second occurring about the middle of August, and the third toward the end of August. The character of the rainfall occurring during these three periods at Portland, Albany, Corvallis, and Eugene is shown in the following table:

Shower period in Willamette Valley, summer of 1907.

Date.	Portland.	Albany.	Corvallis.	Eugene.
First period:	*Inches.*	*Inches.*	*Inches.*	*Inches.*
June 28	0.28	----------	0.18	0.03
June 29	----------	0.16	----------	----------
June 30	----------	----------	----------	.02
July 1	.12	----------	----------	----------
July 2	1.00	----------	----------	----------
July 3	.06	.40	.24	.09
July 4	----------	.02	----------	----------
Total	1.46	.58	.42	.14
Second period:				
August 7	.15	.01	.28	.40
August 8	.07	.62	.21	.55
August 9	----------	.02	----------	.07
August 10	.02	----------	----------	----------
August 11	----------	.04	----------	----------
Total	.24	.79	.49	1.02
Third period:				
August 23	----------	----------	----------	----------
August 24	.69	.12	.44	.45
August 25	.04	.25	.20	----------
August 26	----------	----------	.02	----------
Total	.73	.37	.66	.45
Total for season	2.44	1.74	1.57	2.61

The late spring rainfall ceased on June 15. Between that time and the beginning of the first shower period on June 28 there were a few isolated showers at different points in the valley, but no general rain. The heaviest shower at any point during this period was 0.09 inch at Portland on June 21. During the first period the heaviest rain occurred at Portland on July 2, when 1 inch of rain fell. The only other rainfall of value was at Albany on July 3, when 0.45 inch fell. Between the first and second shower periods there was no rainfall anywhere in the valley except on July 14 and 15 at Eugene, when 0.04 inch and 0.05 inch occurred, respectively. These were so small, however, as to be negligible. For a period of thirty-three days, therefore, the valley was without appreciable rainfall. The total amount occurring during the second shower period was only 0.63 inch, spread over a portion of five days, less than one-eighth inch per day, which was too small an amount to be of any value to crops. Between the second and third shower periods, twelve days, no rain fell, and during

the third shower period the amount of precipitation—but little more than 0.5 inch—was so small as to be of little value on lands that had been subject to hot weather for fifty days. From 1 to 2 inches of rain scattered over a period of ninety days in light showers of from 0.25 to 0.5 inch can do but little good to land that is not exceptionally favored in location, except perhaps in the way of making the atmospheric conditions more favorable.

It is seen, therefore, that notwithstanding the fact that 40 to 45 inches of rainfall occurs annually in the Willamette Valley, its distribution is so uneven that during the three months of the year when most crops make the greatest demand for moisture the rainfall is so light as to make conditions almost comparable with those existing during the same period in the truly arid eastern parts of Oregon and Washington, or elsewhere.

To show how such a deficiency in moisture as occurs in the Willamette Valley each year is met under arid conditions a brief reference will be made to one of the irrigated sections of eastern Washington. Climatic, soil, and crop conditions are of course not truly comparable in the two sections, but are sufficiently so for the purpose in question.

For a number of years the Office of Experiment Stations, through its irrigation investigations, has kept records of the use of water under the Sunnyside Canal system in the Yakima Valley. In 1905 an accurate record was kept of the water applied under seven laterals of the Sunnyside Canal that supplied water to 4,334 acres of land. The irrigation season in that section in 1905 extended over a period of five months, beginning in May, but for the sake of comparison with Willamette conditions, on a three-month basis, the amount of water applied during July, August, and September only is given in the following table:

Water applied to lands under Sunnyside Canal, Yakima Valley, Washington, 1905.

Number of lateral.	July.	August.	September.	Total water.	Acreage.	Depth applied to land.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acres.*	*Inches.*
39.1	380	358	275	1,013	496.4	24.48
34.1	603	600	315	1,518	1,335.0	13.56
32.3	940	956	573	2,469	1,150.0	25.68
29.1	294	272	104	670	333.0	24.12
19.6	273	200	178	651	275.0	28.32
20.4	231	212	106	549	198.0	33.12
27.1	535	301	381	1,217	547.5	26.64
Total				8,087	4,334.9	22.30

It will be noticed that the lateral supplying the least water delivered upon the land 14 inches in depth, while the lateral supplying the greatest amount delivered 33 inches in depth. For all the laterals

the mean amount applied during this three-month period was 22.3 inches. During the three months the rainfall at Sunnyside amounted to 1.77 inches. In the Willamette Valley during the same three months of 1905 the rainfall at the nine stations mentioned averaged 1.58 inches. In the Yakima Valley, therefore, land in crop received during July, August, and September 24 inches of water, while land in crop in the Willamette Valley received only 1.58 inches. This wide variation in the amount of water received by the crops in the two valleys during the three-month summer period is worthy of careful note, and while the two valleys are not exactly comparable, and the amount of water applied under the Sunnyside Canal may have been twice as much as was actually required, the comparison seems to fully warrant the conclusion that could the natural rainfall in the Willamette Valley—2 to 3 inches from June 15 to September 15—be supplemented by irrigation, as is done in the Yakima Valley, a far greater and at the same time safer use could be made of the lands that are now doing only partial duty.

As showing what is already being accomplished with irrigation under climatic conditions similar to those existing in the Willamette Valley, brief reference will be made to the Po Valley in northern Italy,[a] where, notwithstanding the existence of a humid climate, irrigation has been depended upon for centuries to bring about the fullest agricultural production. The upper part of the valley of the Po resembles in many respects the Willamette Valley. On three sides it is surrounded by high mountains—the Alps on the north and east, and the Apennines on the south—from which a network of streams make their way to the Po, the trunk stream of the valley. The valley itself consists of a foothill section and of broad level plains. Situated in practically the same latitude as the Willamette, the climate of the two valleys is very similar. In the provinces of Piedmont and Lombardy the temperature varies from zero as a minimum in winter to 100° as a maximum in summer. The crops raised are those of the temperate zone—cereals, hay, vegetables, and fruit. The rainfall varies from 30 to 40 inches, yet irrigation is practiced extensively and has been practiced for hundreds of years.

The annual rainfall at Milan, the heart of the great irrigated district of Lombardy, averages 40 inches, nearly as much as in the Willamette Valley, while at Turin, the capital of Piedmont, it is 31 inches. The distribution of this rainfall is far more even and more favorable to plant growth than in the Willamette Valley, as indicated in the accompanying summary.

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[a] U. S. Dept. Agr., Office of Expt. Stas. Buls. 144 and 190.

Distribution of rainfall by seasons at Milan and Turin, Italy, and in the Willamette Valley, Oregon.

	Annual rainfall.	Winter.	Spring.	Summer.	Autumn.
	Inches.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Milan	40	21.3	23.9	23.9	30.9
Turin	31	14.7	26.3	31.6	27.4
Willamette Valley	44	38.9	15.4	6.0	39.5

The diagram (fig. 3) shows that for a period of over six months during the crop-growing season the rainfall in the Willamette Valley is only about one-third that at Milan, and that even during the driest month of the year there is on the average more rainfall at Milan than occurs during the whole three months' summer period in the Willamette Valley. In the province of Piedmont alone, which is a little smaller than the Willamette Valley, there is over 700,000

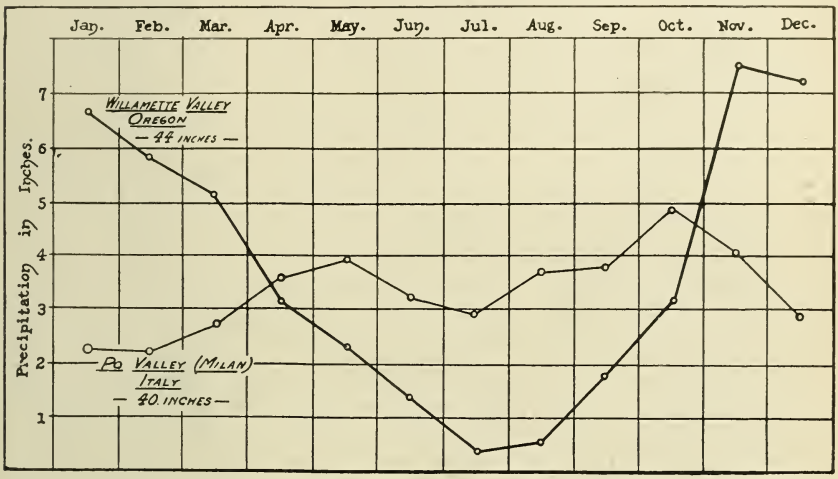

FIG. 3.—Diagram showing average monthly precipitation in Willamette Valley, Oregon, and Po Valley, Italy.

acres under irrigation (1903), twice as much as in the whole State of Oregon, and the canals and laterals built by the Italian Government, to say nothing of those built by private capital, aggregate in this one province a length of 926 miles. Irrigated land under the Villoresi Canal is valued at $160 to $200 per acre, while unirrigated land sells for $100 per acre. On this point Elwood Mead says:

> The conditions under which farmers work in this part of Italy are wholly different from those which prevail in the arid regions of America. In the midst of the Corbetta district there are farms which are being cultivated without irrigation which grow the same crops as surrounding farms that are artificially watered. Farming by rainfall alone here is not unlike farming in Kentucky, Tennessee, southern Missouri, and northern Arkansas. The rainfall in Italy is, if anything, a little greater and is equally well distributed.

In the fields devoted to wheat only one crop a year is grown where irrigation is not practiced, but where the land is irrigated a good crop of corn, beans, or cabbage can be planted and brought to maturity after the wheat is harvested. Without irrigation clover and alfalfa, if sown with wheat, make a small growth, but with irrigation a good crop can be cut the same year after the wheat is harvested and the stand in succeeding years is better because of the vigorous growth while the plants were young, due to irrigation.

Numerous cases of serious damage in the Willamette Valley caused by a deficiency of moisture in the soil and in which great benefit would have resulted from irrigation if it had been provided at the right time might be cited. The hopyards, especially those on the uplands, are known to suffer more or less each season from drought, and in some seasons owners estimate the decrease in yield at as much as 30 per cent in some cases. In the issue of the Morning Oregonian of Portland of August 13, 1906, there appeared a review by special correspondence of the hop situation in the valley in which the shortage due to drought was estimated at from 10 to 30 per cent.

The hop crop is but one of the many crops that are subject to damage from the dry summers. Potatoes, vegetables, hay crops, and fruits are at the mercy of the weather during this period, and when rains do not occur they show the effects of the deficiency by decreased yields and inferior quality. It would therefore seem that although crops can be grown without irrigation there is beyond question a need for it in the Willamette Valley, and the more intensive agriculture becomes the greater will be the need.

PLAN OF IRRIGATION EXPERIMENTS.

The experimental work in irrigation now in progress is being carried on largely in the vicinities of Corvallis, Albany, and Hillsboro, where opportunity is afforded for a comprehensive study of nearly every phase of the general problem. All of the experimental work is being conducted on a cooperative basis with persons who have become interested in the question and who have been willing to bear the greater part of the labor and expense necessary to the experiments. Those with whom this Office is cooperating and the location of the experimental tracts are as follows:

The State experiment station, 1 mile west of Corvallis.

Mr. Oswald West, owner of hopyard, 3 miles south of Corvallis.

Mr. Robert Gellatly, owner of market garden, 12 miles west of Corvallis.

Messrs. Cockerline and Howard, owners of diversified farm, 1 mile south of Albany.

Mr. George R. Bagley, owner of diversified farm, 6 miles north of Hillsboro.

Mr. A. M. Stanton, owner of diversified farm, 2 miles west of Hillsboro.

Upon the experiment station farm no effort is made to make the crops raised produce a revenue in proportion to the cost of raising them, the prime object being to determine the efficacy of various methods of treatment, so that these methods may be put to a practical test at the other stations, where the main object is to secure the greatest revenue from the crops produced. At these other stations all experiments are conducted on a field basis and all operations carried on on a commercial scale.

As already stated, conclusive results can not be reported from the experiments begun the past season, because so much of the work was largely preparatory. It is possible, however, to present some partial results from the experiments at the different stations and also to give some general results obtained at other points where water has been used on crops during the dry season, which will throw considerable light upon the question of what irrigation may be expected to accomplish and will, it is hoped, encourage those most interested to undertake similar investigations of their own, thereby extending the field from which the exact value of irrigation in the valley may be determined.

EXPERIMENT IN COOPERATION WITH THE STATE EXPERIMENT STATION, CORVALLIS.

The work at the experiment station farm is purely experimental and has for its object a careful study of the more involved phases of the problem. Practically all of the conditions affecting the experiments are under control. The experiments are conducted on a plat basis. Six acres are divided into one-half acre plats on which the different crops of the valley—hops, clover, vetch, alfalfa, potatoes, corn, etc.—can be raised. Plats are laid off in duplicate, one being irrigated and the other unirrigated, so that comparison can be made. Water is secured from Oak Creek by means of a small pumping plant which was installed during the summer of 1907. The equipment consists of a 4-horsepower gas engine and a 3½-inch centrifugal pump (fig. 4). The water is pumped to a height of 15 feet and discharged into a flume 700 feet long that delivers it to the experimental plats. Water is distributed to the plats from small wooden flumes as shown in figure 5. A weir and automatic recording device are provided for the purpose of determining the exact amount of water applied to the different plats.

Corn.—A plat of one-half acre was planted to field corn on June 14, 1907. Between June 20 and 28 the pumping plant was installed and on June 29, when the corn was about 3 inches high, the ground was

irrigated for the first time. The water was distributed from a head flume into furrows made 3 or 4 inches deep with a shovel plow. The furrow method was adopted not only with the corn and potatoes but also with alfalfa, it being possible in this way to prevent the surface soil from baking and forming a crust. In a very few days the irrigated corn showed the effect of the water and in three weeks it had a decided advantage over the unirrigated. On July 29 a second irrigation was given to a part of the corn. The corn was harvested the first week in October. The yields were as follows:

Yield of irrigated and unirrigated corn at Corvallis, Oreg.

Treatment.	Green fodder per acre.	Percentage of increase.
	Pounds.	*Per cent.*
Unirrigated	5,647	00
Irrigated once	7,000	24
Irrigated twice	9,666	71

FIG. 4.—Pumping plant at Oregon Experiment Station.

Six average unirrigated stalks with ears weighed 10 pounds. Six average stalks twice irrigated weighed 16.5 pounds. Twelve unirrigated ears weighed 5 pounds 12 ounces; twelve irrigated ears twice irrigated weighed 7 pounds 4 ounces; increased weight due to irrigation, 26 per cent.

The results, however, should be considered only tentative, as illustrating what irrigation may be expected to do, because the conditions under which the crop was grown were not normal.

It will be noticed that the yields reported are not large, a good yield for corn growing in the valley being 60 bushels per acre. This was due to the soil not being in proper condition before planting and to late planting.

Potatoes.—The area planted to potatoes was the duplicate of that planted to corn. The potatoes were planted at the same time as the corn and received the same treatment. The yields were as follows:

Yields of irrigated and unirrigated potatoes at Corvallis, Oreg.

Treatment.	Yield of tubers per acre.	Percentage of increase.	Marketable tubers.
	Pounds.	*Per cent.*	*Per cent.*
Unirrigated	2,604	000	89.2
Irrigated once	6,760	160	88.0
Irrigated twice	7,500	180	93.2

FIG. 5.—Method of irrigating alfalfa and corn, Oregon Experiment Station.

EXPERIMENTS ON THE MARKET GARDEN OF ROBERT GELLATLY, NEAR PHILOMATH.

The purpose of this experiment is to determine the value of irrigation in the production of vegetables. For market gardens and for the raising of vegetables in general irrigation is without doubt of great value. This has already been demonstrated in the market gardens throughout the valley. For the production of the first crop of vegetables, especially the early maturing varieties, irrigation is not needed if sufficient cultivation is given. For a second crop of veg-

etables and such slow-growing crops as celery, cauliflower, and the like, irrigation eliminates all possibilities of damage from drought and produces, even in average seasons, better results than are secured by dependence upon the natural rainfall. A tract of 2 acres is devoted to the experiment, the soil being a rich creek-bottom loam, which absorbs water readily. Water is received from a small creek by gravity flow, measured over a weir. Some interesting results from the irrigation of onions were obtained the past season. The coming season it is planned to extend the investigation to other root crops.

Onions.—Mr. Gellatly has for a number of years been raising vegetables under irrigation. In making the test with onions it was arranged to leave a part of the onion patch unirrigated, twenty-four rows, each 60 feet in length, being set apart for this purpose. The entire patch included an area of 10,000 square feet. The rows were spaced 1 foot apart and arrangements made for supplying water to the rows from a head ditch. The crop was given four irrigations during the season, water being applied as follows:

Water applied to onions at Philomath, Oreg.

	Feet.
First irrigation	0.79
Second irrigation, June 20–22	1.23
Third irrigation, July 12	.73
Fourth irrigation, July 23–26	.76
Total for season	3.51

The twenty-four rows that were not irrigated showed a marked contrast to the irrigated rows by the time the second watering was given. These rows did not have the color nor the size of the irrigated rows and clearly showed the need of moisture. It was not possible to do away entirely with subirrigation on the unirrigated rows, but the difference in the yield between the irrigated and unirrigated rows very clearly indicated the value of irrigation when the moisture in the soil is deficient. When the onions were harvested, twenty-four representative rows were selected from the irrigated area for comparison with the twenty-four unirrigated rows. The results were as follows:

Yield of irrigated and unirrigated onions, Philomath, Oreg.

	Pounds.
Yield from 24 irrigated rows	850
Yield from 24 unirrigated rows	350
Increase	500

Not only was there an increase in yield, but there was a marked difference in both size and quality in favor of the irrigated onions. The patch, less than one-fourth acre, yielded 150 bushels of onions. The onions were grown upon a rich alluvial soil, which is open and porous, has good drainage, and absorbs water readily.

EXPERIMENTS ON THE HOPYARD OF OSWALD WEST, NEAR CORVALLIS, OREG.

The yard upon which these experiments are being made is on Kigers Island, 3 miles south of Corvallis. The soil is a sedimentary deposit of fine silt underlaid by a porous, gravelly stratum and dries out to such an extent that the hops, especially those at the higher elevations, suffer from lack of moisture. The equipment for the irrigation of the yard the past season consisted of a 6-horsepower portable engine and a 4-inch centrifugal pump (fig. 6). Water was lifted 25 feet and discharged into a flume 800 feet long, which conveyed it to the yard. Then it was distributed as shown in figure 7. The plant, however, was not installed until late in the season, about the middle

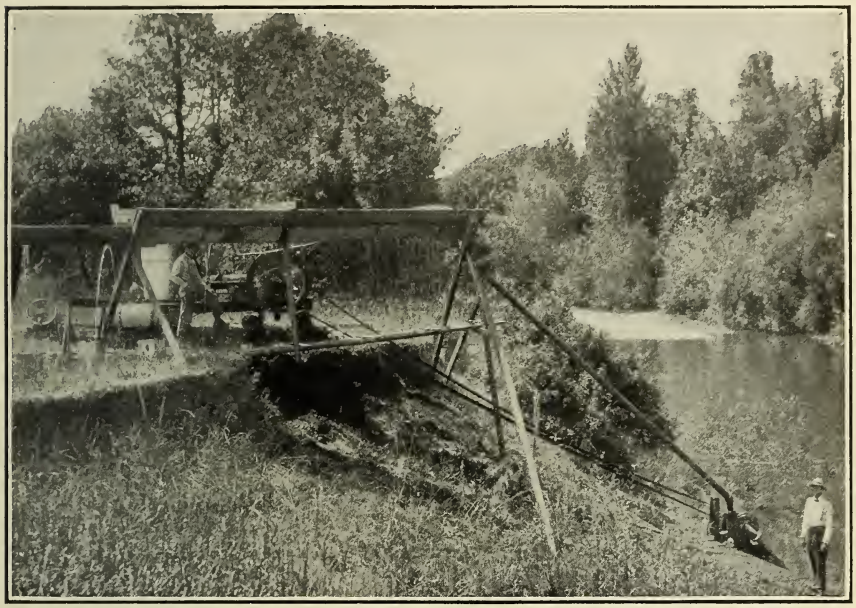

FIG. 6.—Pumping plant of Oswald West, near Corvallis, Oreg.

of July, so that the best results could not be secured. The water should have been applied at least two weeks earlier in the season. Regardless of this, the results were most gratifying. In reporting the experiment, Mr. West says:

> The tract irrigated was a hopyard containing about 25 acres. In 1906 the yard produced without irrigation about 800 pounds per acre, which is a little less than an average yield for yards in the Willamette Valley; many yards in the river bottoms yield, however, a ton to the acre, and even more. Last summer less than one-half of the yard was irrigated and only for a period of about fifteen days in July and August. The yard was irrigated by pumping from the Willamette River with a 4-inch pump and 6-horsepower gasoline engine. About 150 gallons of distillate was used for fuel, which cost 11.5 cents per gallon. One

man was able to look after the engine and pump and do the ditching, which was done with a plow. The yield from the entire yard averaged 1,150 pounds per acre, which would mean about 80 per cent, as the crop on the unirrigated part of the yard was about the same as it was in the preceding year, except that portions of it may have derived benefits through subirrigation, which might have increased the yield over the preceding year.

The results have shown that irrigation can be carried on successfully in the Willamette Valley and, on places situated similar to mine, can be conducted at very little cost, and that the yield of any crop can be increased at least from 75 to 100 per cent. I intend to irrigate the entire yard next year, and, by enlarging the plant, I hope to eventually have the whole place—150 acres—under irrigation.

After seeing the result of the experiment I am surprised that this matter has not received earlier attention. The Government has been endeavoring to get

FIG. 7.—Distributing irrigation water in hopyard of Oswald West, near Corvallis, Oreg.

people to take hold of the matter, but they have been slow to do anything. The results obtained last year by the few who irrigated under your direction should satisfy the most skeptical that irrigation in this valley will be a success and that they will all come to it sooner or later.

Some general information bearing on the value of irrigation in the production of hops has been gathered, and this, although incomplete, is included for the benefit of those hop growers who have come to realize that their hop yields are not all they should be in seasons of scanty rainfall, and are desirous of improving existing conditions by providing the means that will not only insure the yield of the hopyard but increase it in cases where the yard is located on upland or upon porous gravelly bottom land.

In June, 1906, the writer interviewed a large number of hop growers of the valley to ascertain the extent to which hops are damaged by drought. From these interviews it was gathered that on the average there are about three seasons in every ten in which serious damage results from drought, during which the yield is cut down fully one-third, and that during every season the conditions are such that one good irrigation, if provided at the proper time, would be of immense benefit.

Seavey Brothers, of Eugene, Oreg., reported that in 1904 and 1905 their hops suffered a decrease in yield of 30 per cent, due entirely to droughts in the early part of the growing season. The average yield of their yard is 1,500 to 2,000 pounds per acre in good seasons, while in dry years such as the two mentioned the yield is 1,000 to 1,200 pounds per acre, and not only is the yield decreased but the size and quality of the hops are reduced.

EXPERIMENTS IN COOPERATION WITH G. R. BAGLEY, NEAR HILLSBORO, OREG.

The tract upon which these experiments are being conducted is located about 6 miles north of Hillsboro. Prior to the purchase of the tract by Mr. Bagley in 1906 the land had for many years been used almost exclusively for grain growing. Mr. Bagley's intention is to develop the property as a diversified farm, and irrigation, which is easily and cheaply provided, is to be used to bring about the fullest development. A dairy herd has been placed upon the place so that an extremely practical test of the value of irrigation can be made, it being the intention to keep a complete record of all farming operations, together with a record of all crop yields and their disposal. A preliminary experiment in the irrigation of red clover, which was made by Mr. Bagley the past season and which is referred to later, indicates results which may be expected from future experiments at this place. The soil is representative of the prairie soils common to the north end of the valley. Water for irrigation is secured from Dairy Creek by gravity flow through an old mill race, which is part of the property owned by Mr. Bagley. Mr. Bagley began in the fall of 1906 the preparation of 8 acres of land for the experiment. It was found that at a depth of 8 to 10 inches there had been formed a plow sole, or artificial hardpan, that was so hard and impervious as to hinder the penetration of roots to a greater depth. To break up this plow sole the greater part of the field was subsoiled to a depth of 16 to 20 inches. The part of Mr. Bagley's letter giving details of the experiment follows:

It has long been the opinion of farmers of the Willamette Valley and particularly the farmers of Tualatin Plains that irrigation of the prairie land was not only impossible but particularly injurious, causing the land to pack, bake,

and sour; in fact, this opinion was so widespread and fixed that during my residence of twenty years in this community I have never heard of a single attempt to irrigate any of the prairie lands of the Tualatin Plains.

The 8 acres upon which the experiment was conducted is a clay loam soil about 4 feet deep and had never been plowed over 8 inches in depth and is so situated as to be naturally fairly well drained, and in 1906 produced a medium crop of fall oats.

All soil in this district of the same character upon continuous cultivation has a tendency to form a crust at the plow level, and the tract irrigated was no exception. I therefore plowed the tract 12 inches deep with an ordinary walking plow and subsoiled 8 inches deep, thoroughly breaking the crust, and although the fall of 1906 and especially November was very wet, seeded the tract in winter vetch and oats on November 24. The winter of 1906–7 was rather severe on vetch and, while the vetch crops in the same character of soil in the community were affected by the winter, this crop was not injured in the least by the freezing weather.

On February 19, 1907, I seeded the tract in red clover, using 10 pounds of seed per acre, sowing the same upon the snow.

My principal reason for sowing red clover with the vetch crop was to enable me to get as much crop as possible from the land, because I had but 40 acres of tillable land and had 40 head of cattle to support, and vetch and clover were the principal crops I desired. I was also satisfied (notwithstanding assertions made to the contrary by experienced farmers that I could not get a stand of clover with vetch) that by cutting the vetch early and furnishing the clover with water at the proper time I could get a good stand of clover and also grow a crop the same year, as it has been evident to me for a number of years that all clover lacked in this county was water at the proper season, and my faith was justified by the results, for I cut the vetch crop between June 28 and July 3, all of which was removed by July 5. The clover plants were small and delicate and did not appear to be very plentiful, the ground being apparently quite bare. No special preparations were made to distribute the water, except one ditch running upon the highest ground. The water was applied to the clover between July 10 and 25, the time consumed in watering the same being caused by the loss of a head of water, occasioned by the operation of the flouring mill, which would lower the water (in a supply ditch), so that the land could not be irrigated.

The water was applied to the land by opening the main ditch and damming the dead furrows at convenient distances and allowing the water to percolate to the center of the land.

With proper care the whole tract could have been irrigated with the means at hand in two days. A portion of the land seeded in red clover had not been subsoiled.

In fifty-two days from the day of applying the water, the clover on the subsoiled land reached a growth of 36 inches in length and was of a deep green, healthy color. That upon the land not subsoiled reached a growth of about 10 inches and was of a light green color and sickly appearance.

On August 15 we began soiling the crops for the cows and continued to soil the same during half of August, all of September, all of October, and part of November, and upon more than one-half of the tract to which the water was applied cut the second crop of clover. Meanwhile, during the dry months of August, September, and October the land was moist and springy and needed no further irrigation and had not in any sense packed.

I had no means of securing accurate weights of the crops removed from the tract during the year 1907, but estimated that I secured 20 tons of vetch hay, 100 tons of green clover, 4½ tons of clover hay, and 8 tons of clover silage; and at present the clover is from 6 to 10 inches high, which will make an excellent mulch.

This is the first instance within my knowledge, or within the knowledge of any of the farmers of this community, that a crop of clover was produced in the year it was seeded; in this instance two crops of clover were produced in the year it was seeded, a portion of which was used for silage.

In applying the water upon the land I aimed to give the ground a thorough soaking, applying as much water as the ground would hold and then cut off the supply. The coming year I expect to irrigate 12 additional acres and the next year 40 additional acres, as I purchased 100 acres of cultivable land immediately adjoining. In time I expect to have 140 acres under irrigation and 60 acres in alfalfa.

Regardless of opinions of old settlers, I am of the opinion that proper irrigation is exactly what the soil in its present condition actually needs. The effect of the experiment is startling. Since you left here there have been dozens of farmers called for the purpose of discussing the irrigation question with me, and in fact Mr. Campbell, Doctor Tamiesie, Mr. Henderson, and Zina Wood expect to try it next year. About two years more and the skeptics will fade away and the progressive farmers of Tualatin Plains will be looking for the installment of a permanent irrigation system which will enable them to enjoy the fullest production of crops.

The results secured by Mr. Bagley, while they can not be stated in definite terms, show most conclusively the value of irrigation in producing clover. Had it not been for the one irrigation in July, the young clover plants would have either died from lack of moisture or struggled on through the season, perhaps to yield one crop the following year. The one irrigation cost only the labor of one man for not to exceed two days, bringing the cost of labor and irrigation to less than 50 cents an acre.

The growing importance of the dairy industry of the Willamette Valley is fast bringing the production of forage crops to one of the most important phases of farm practice. The climatic conditions during the growing period of these crops are such, however, as to make their full development difficult. Owing to the mild, moist spring, most hay crops, if permitted to grow, are ready for cutting toward the first of June, but as a rule a rainy period may be expected about this time and unless the time of curing be delayed beyond this the hay crop is very apt to be damaged while curing. To prevent this and to delay the haying season until more settled weather can be counted upon, the practice of pasturing the crop in its early stages of growth, in March or April and May, has come to be quite common. By so doing, however, the growth of the second crop of such forage plants as produce more than one crop in a season is delayed and the dry summer period comes on before the plants can make much headway toward a second crop. As a result only one good crop of hay is

secured, with one light crop following that is either cut for hay or allowed to go to seed. With one or two good irrigations to put the soil in good condition three good crops of hay can be confidently expected.

Another effect of the dry summer season is to deprive the dairy herd of pasture and green feed during the very months of the year when they should have it. Through the balance of the year, by judicious selection of soiling crops, dairy cows can be given feed, even throughout the winter, when soiling crops such as kale can be resorted to. But in the summer it is common practice now to depend upon cured hay or silage after the pastures are dried up. Irrigation may be expected to improve this condition also.

As shown by Mr. Bagley's experiment, irrigation will also make a clover crop possible the same season in which it is seeded. Common practice with clover now is to seed one year and get no returns from the land till the following year.

EXPERIMENTS IN COOPERATION WITH A. N. STANTON, NEAR HILLSBORO, OREG.

The experiments to be conducted here will be similar to those conducted upon the Bagley farm, except that the water is pumped from Dairy Creek. The soil is also different from that on the Bagley farm, having been heavily timbered and cleared for cultivation. The experiments embrace the irrigation of forage crops and root crops. A dairy herd is maintained on this farm also, which gives added value to experiments on account of their relation to the dairy industry.

EXPERIMENTS IN COOPERATION WITH H. N. COCKERLINE AND J. A. HOWARD, NEAR ALBANY, OREG.

These experiments are being made upon a tract of land 1 mile south of Albany, and are to determine the value of both irrigation and drainage in bringing back to a state of productiveness land which has been abused for years in grain cultivation until it no longer responds to cultivation. The irrigation experiments here have as their primary object a determination of the value of irrigation on a dairy farm, it being the intention to show what can be done with the so-called "worn-out" lands of the valley. A tile drainage system is now being installed by this Office, which it is hoped will relieve the wet condition of the soil during the rainy season and put the soil in a fit condition for cultivation in the early spring. It is thought that by the growth of leguminous crops, by green manuring, and by thorough cultivation the land can be brought back to a productive condition. Water for irrigation will be secured by gravity flow and will be used to aid the growth of forage crops during the dry season.

TENTATIVE CONCLUSIONS.

The evidence presented, though fragmentary and incomplete, indicates the need of irrigation in the valley and that it will be of benefit in the following ways:

(1) It will serve as crop insurance for those crops which in ordinary years are matured before the dry season, but suffer during exceptional periods of early drought.

(2) The mild climate makes it possible for the dairy herd to secure food during all seasons of the year except the summer, but under present conditions it is necessary to feed them either dry feed or silage during the summer months when pastures are dried up. Irrigation will produce green food during this dry period and will make it possible to carry the herd into the winter season in full milk.

(3) The market garden industry is coming to depend upon irrigation for its fullest development, and already in many cases market gardeners have provided themselves with a small water supply which they use in the production of late crops of vegetables which could not be matured without it. These late vegetables and berries go on the market when the earlier crops have become exhausted. This is especially true of such vegetables as celery, cauliflower, and potatoes.

(4) Both irrigation and drainage will doubtless be of service in reclaiming a vast area of prairie land which, owing to its poor natural drainage and to the abuse it has received in grain cultivation, lies in a water-logged condition till late in the spring and which even when cultivated and subsoiled is wholly incapable of producing normal crops. Drainage of these lands will relieve their water-logged condition and make them more responsive to cultivation, while irrigation will carry the crops grown on them through the dry period.

Recommended for publication.

A. C. True, *Director.*

Publication authorized.

James Wilson,
Secretary of Agriculture.

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